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4D modeling and simulation of magma dynamics

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The processes occurring in magma reservoirs play a crucial role in determining the evolution of a volcanic system and ultimately the occurrence of an eruption. The complexity of such processes often lead to over-simplifications, like lumped approaches that neglect the internal dynamics and the heterogeneities of magma chambers. We have engaged in developing a 4D (space-time) numerical model that is able to take into account the complex physics of multiphase, multicomponent magmatic mixtures, as well as the complex geometries of multiple magma chamber-dyke systems. Our C++ parallel numerical code employs a space-time stabilized finite element method, and solves the equations of conservation of mass, momentum and energy in compressible-to-incompressible regimes to determine the space distribution and evolution of quantities such as composition, density, velocity, pressure, temperature, volatile partitioning,viscosity, etc. We present here the model formulation and its benchmarking. First test applications to volcanological problems include magma chamber replenishment and rejuvenation, magma mingling and mixing, reservoir cooling, all of them usually evaluated as first-order in affecting volcano evolution. Computed density changes can be readily translated in gravity signals, while pressure evolutions constitute the driving force for ground displacement measured at the Earth surface. Our approach is thus expected to lead to more realistic interpretation of geophysical signals at volcanoes.